DEVICE AND METHOD FOR OPERATING VOICE-SUPPORTED SYSTEMS IN MOTOR VEHICLES

FIELD OF THE INVENTION

The present invention relates to a method and to a device for operating voice-enhancement systems, such as communication and/or intercom/two-way intercom and/or duplex telephony devices in motor vehicles, where voice signals are picked up via a microphone system and routed to at least one loudspeaker.

BACKGROUND INFORMATION

Methods of this kind are used in motor vehicles for voice-supported duplex telephony or for supporting voice input-controlled electronic or electrical components. The fundamental difficulty that arises is that, depending on the particular operating state, there is background noise in the motor vehicle. This masks the voice commands. Intercom and two-way intercom systems in motor vehicles are mainly advantageously used in large vehicles, minibusses and the like. However, they can also be used in normal passenger cars. When using voice-controlled input units for electrical components in motor vehicles, it is still very important for the background noise to be suppressed or for the voice command to be filtered out.

Thus, a voice-recognition device for a motor vehicle is described in European Patent Application No. 0 078 014, where the status of engine operation and/or motor vehicle movement is signaled or fed in, via sensors, to the amplifier system of the voice-recognition device. Based on this, a noise-level control is then used to attempt to filter out the voice command from the background noise.

A filtering operation is described in PCT International Published Patent Application No. WO 97/34290, where periodic interfering noise signals are filtered out by determining

their periods and by using a generator to interfere with them, so that the voice signal remains.

In German Published Patent Application No. 197 05 471, it is described to support a voice recognition with the aid of transversal filtering.

In German Published Patent Application No. 41 06 405, a method is described for subtracting noise from the voice signal, a multiplicity of microphones being used. A duplex telephony device having a plurality of microphones is discussed in German Published Patent Application No. 199 58 836.

In German Published Patent Application No. 39 25 589, it is described to use a multiple microphone system, where, in motor vehicle applications, one of the microphones is placed in the engine compartment and one other microphone in the passenger compartment. A subtraction of both signals then follows. The disadvantage in this context is that only the engine noise or the actual running noise of the vehicle itself is subtracted from the total signal in the passenger compartment. Specific secondary noises are disregarded in this case. Also lacking is a feedback suppression. Everywhere that microphones and loudspeakers are placed in an acoustically coupleable vicinity, the acoustic signal that is extracted, coupled out or decoupled at the loudspeaker is fed back into the microphone. The result is a so-called feedback, and a subsequent overmodulation. Methods for avoiding such an overmodulation are described in European Published Patent Application No. 1 077 013, PCT International Published Patent Application No. WO 02/069487, and PCT International Published Patent Application No. WO 02/21817.

It is an object of the present invention to provide a method and a device that may improve the verbal communication among the occupants of a vehicle.

SUMMARY

The above and other beneficial objects of the present invention may be achieved by providing a method and a device as described herein.

The above object may be attained in that, for the operation of a voice-supported system, such as a communications and/or duplex telephony device in a motor vehicle, using at least one microphone and at least one loudspeaker to reproduce a signal generated by the microphone, as well as using a bandpass filter arranged between the microphone and the loudspeaker, the power of a signal is determined as a function of a frequency, and the bandpass filter is adjusted or set as a function of at least one local maximum of the power of the signal as a function of the frequency.

A local maximum of the power of the signal as a function of the frequency may include also the global maximum of the power of the signal as a function of the frequency.

In an example embodiment of the present invention, the local maximum of the power of the signal may be determined as a function of a derivative, e.g., the first derivative, of the power of the signal with respect to the frequency.

In an example embodiment of the present invention, an edge or slope signal may be formed using the first derivative of the power of the signal with respect to the frequency, which takes on a first binary value when the first derivative of the power of the signal with respect to the frequency is greater than or equal to zero, and which takes on a second binary value when the first derivative of the power of the signal with respect to the frequency is less than zero, the local maximum of the power of the signal being determined as a function of the first derivative of the slope signal.

In an example embodiment of the present invention, the presence of a local maximum of the power of the signal may only be assumed if the first derivative of the slope signal is less than zero.

The foregoing object may additionally be attained in that, for the operation of a voice-supported system, such as a communications and/or duplex telephony device in a motor vehicle, using at least one microphone and at least one loudspeaker to reproduce a signal generated by the microphone, as well as using a bandpass filter arranged between the microphone and the loudspeaker, the power of a signal may be determined as a function of a frequency, and the bandpass filter may be adjusted as a function of a derivative of the power of the signal with respect to the frequency.

In an example embodiment of the present invention, the bandpass filter may be adjusted as a function of at least two local maxima of the power of the signal as a function of the frequency.

In an example embodiment of the present invention, the bandpass filter may be adjusted as a function of the first derivative of the power of the signal with respect to the frequency.

In an example embodiment of the present invention, a slope signal may be formed using the first derivative of the power of the signal with respect to the frequency, which takes on a first binary value when the first derivative of the power of the signal with respect to the frequency is greater than or equal to zero, and which takes on a second binary value when the first derivative of the power of the signal with respect to the frequency is less than zero, the bandpass filter being adjusted as a function of the slope signal or of the first derivative of the slope signal.

In an example embodiment of the present invention, all local maxima may be determined in one frequency range. In an example embodiment of the present invention, the global maximum may be determined in that frequency range.

In an example embodiment of the present invention, the bandpass filter may be adjusted so that it blocks the portion of the signal generated by the microphone at a notch frequency only when the ratio:

at least of the power of the signal generated by the microphone at the frequency at which the power of the signal generated by the microphone is a maximum

to

the average value of the power of the signal generated by the microphone at additional frequencies of the signal generated by the microphone

is greater than a feedback-power threshold (ratio threshold, OutGrdRatioThreshold).

In an example embodiment of the present invention, the bandpass filter may be adjusted so that it blocks the portion of the signal generated by the microphone at a notch frequency only when the ratio:

at least of the power of the signal generated by the microphone at the frequency at which the power of the signal generated by the microphone is a maximum

to

the average value of the power of the signal generated by the microphone at additional frequencies of the signal generated by the microphone

is greater than a feedback-power threshold (RatioThreshold, OutGrdRatioThreshold) for longer than a time-ratio threshold (BinRatioTimeThreshold).

In an example embodiment of the present invention, the bandpass filter may be adjusted so that it blocks the portion of the signal generated by the microphone at a notch frequency only when the ratio:

of the power of the signal generated by the microphone at the frequency at which the power of the signal generated by the microphone is a maximum, plus/or of the power of the signal generated by the microphone at one of the further frequencies of the signal generated by the microphone which are adjacent to the frequency at which the power of the signal generated by the microphone is a maximum

to

the average value of the power of the signal generated by the microphone at additional frequencies of the signal generated by the microphone

is greater than a feedback-power threshold (RatioThreshold, OutGrdRatioThreshold).

In an example embodiment of the present invention, the bandpass filter may be adjusted so that it blocks the portion of the signal generated by the microphone at a notch frequency only when the ratio:

of the power of the signal generated by the microphone at the frequency at which the power of the signal generated by the microphone is a maximum, plus/or of the power of the signal generated by the microphone at one of the further frequencies of the signal generated by the microphone which are adjacent to the frequency at which the power of the signal generated by the microphone is a maximum

to

the average value of the power of the signal generated by the microphone at additional frequencies of the signal generated by the microphone

is greater than a feedback-power threshold (RatioThreshold, OutGrdRatioThreshold) for longer than a time-ratio-threshold (BinRatioTimeThreshold).

In an example embodiment of the present invention, the bandpass filter may be adjusted so that it blocks the portion of the signal generated by the microphone at a notch frequency only when the ratio:

of the power of the signal generated by the microphone at the frequency at which the power of the signal generated by the microphone is a maximum, plus/or the power of the signal generated by the microphone at the frequency of the signal generated by the microphone:

which is directly adjacent to the frequency at which the power of the signal generated by the microphone is a maximum; and

at which the power is greater than at a frequency which is also directly adjacent to the frequency at which the power of the signal generated by the microphone is a maximum

to

the average value of the power of the signal generated by the microphone at additional frequencies of the signal generated by the microphone

is greater than a feedback-power threshold (RatioThreshold, OutGrdRatioThreshold).

In an example embodiment of the present invention, the bandpass filter may be adjusted so that it blocks the portion of the signal generated by the microphone at a notch frequency only when the ratio:

of the power of the signal generated by the microphone at the frequency at which the power of the signal generated by the microphone is a maximum, plus/or the power of the signal generated by the microphone at the frequency of the signal generated by the microphone:

which is directly adjacent to the frequency at which the power of the signal generated by the microphone is a maximum; and

at which the power is greater than at a frequency which is also directly adjacent to the frequency at which the power of the signal generated by the microphone is a maximum

to

the average value of the power of the signal generated by the microphone at additional frequencies of the signal generated by the microphone

is greater than a feedback-power threshold (RatioThreshold, OutGrdRatioThreshold) for longer than a time-ratio-threshold (BinRatioTimeThreshold).

In an example embodiment of the present invention, the bandpass filter may be adjusted so that it blocks the portion of the signal generated by the microphone at a notch frequency only when the ratio:

> of the power of the signal generated by the microphone at the frequency at which the power of the signal generated by the microphone is a maximum, plus the power of the signal generated by the microphone at the frequency of the signal generated by the microphone:
>
> > which is directly adjacent to the frequency at which the power of the signal generated by the microphone is a maximum; and
> >
> > at which the power is greater than at a frequency which is also directly adjacent to the frequency at which the power of the signal generated by the microphone is a maximum

to

> the average value of the power of the signal generated by the microphone of all, at least essential, additional (investigated) frequencies of the signal generated by the microphone

is greater than a feedback-power threshold (RatioThreshold, OutGrdRatioThreshold).

In an example embodiment of the present invention, the bandpass filter may be adjusted so that it blocks the portion of the signal generated by the microphone at a notch frequency only when the ratio:

> of the power of the signal generated by the microphone at the frequency at which the power of the signal generated by the microphone is a maximum, plus the power of the signal generated by the microphone at the frequency of the signal generated by the microphone:

which is directly adjacent to the frequency at which the power of the signal generated by the microphone is a maximum; and

at which the power is greater than at a frequency which is also directly adjacent to the frequency at which the power of the signal generated by the microphone is a maximum

to

the average value of the power of the signal generated by the microphone of all, at least essential, additional (investigated) frequencies of the signal generated by the microphone

is greater than a feedback-power threshold (RatioThreshold, OutGrdRatioThreshold) for longer than a time-ratio-threshold (BinRatioTimeThreshold).

In an example embodiment of the present invention, the feedback-power threshold (RatioThreshold, OutGrdRatioThreshold) may be established as a function of an output signal of the bandpass filter.

In an example embodiment of the present invention, the feedback-power threshold (RatioThreshold, OutGrdRatioThreshold) may be between 20 and 40.

In an example embodiment of the present invention, the bandpass filter may be adjusted so that it blocks the portion of the signal generated by the microphone at a notch frequency only when the ratio:

of the power of the signal generated by the microphone at the frequency at which the power of the signal generated by the microphone is a maximum

to

the average value of the power of the signal generated by the microphone at further frequencies at which the power of the signal generated by the microphone has a local maximum

is greater than an additional power threshold (RichContentThreshold).

In an example embodiment of the present invention, the bandpass filter may be adjusted so that it blocks the portion of the signal generated by the microphone at a notch frequency only when the ratio:

> of the power of the signal generated by the microphone at the frequency at which the power of the signal generated by the microphone is a maximum

to

> the average value of the power of the signal generated by the microphone at all further (investigated) frequencies at which the power of the signal generated by the microphone has a local maximum

is greater than an additional power threshold (RichContentThreshold).

The power of the signal generated by the microphone at the frequency at which the power of the signal generated by the microphone is a maximum, and/or the power of the signal generated by the microphone at a frequency at which the power of the signal generated by the microphone has a local maximum, in the sense of the foregoing, may include alternatively or additionally also the power that the signal has in response to a closely adjacent frequency of above-named frequency and which (still) has a similar high power, such as the maximum in each case.

In an example embodiment of the present invention, the additional power threshold (RichContentThreshold) may be between 20 and 50, e.g., between 30 and 40.

In an example embodiment of the present invention, the bandpass filter may be adjusted as a function of its output signal.

In an example embodiment of the present invention, the bandpass filter may include a notch filter or a filter bank, e.g., a multifilter, having at least one notch filter. The filter bank may include, for example, 10 notch filters.

Further aspects, features and details are set forth below in the following description of exemplary embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates a motor vehicle.

Figure 2 schematically illustrates an exemplary embodiment of a device according to the present invention.

Figure 3 schematically illustrates a notch filter.

Figure 4 schematically illustrates a filter bank.

Figure 5 schematically illustrates an exemplary embodiment for a flow diagram implemented in a decision logic.

Figure 6 schematically illustrates an power-frequency diagram.

Figure 7 schematically illustrates an exemplary embodiment of query 41 in Figure 5.

Figure 8 is a schematic power-frequency diagram.

Figure 9 is a schematic power-frequency diagram.

DETAILED DESCRIPTION

Figure 1 is a schematic inside view of a motor vehicle 1 from above. In this context, reference numerals 2 and 3 indicate the front seats, and reference numerals 4, 5 and 6 indicate the rear seats of the motor vehicle. Reference numerals 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 and 20 indicate loudspeakers. Reference numerals 21, 22, 23 and 24 indicate microphones. Loudspeakers 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 and 20 belong, in part, to a music system and, in part, to a communication and/or intercom/two-way intercom device. They may also be used by both systems.

In the present exemplary embodiment, loudspeakers 9, 17, 18, 19, 20 output a signal generated by microphone 21, loudspeakers 7, 17, 18, 19, 20 output a signal generated by microphone 22, loudspeakers 7, 9, 19, 20 output a signal generated by microphone 23, and loudspeakers 7, 9, 17, 18 output a signal generated by microphone 24. In this manner, the possibility of verbal communication in a motor vehicle is supported. In this context, in principle, the more strongly a signal is amplified between one of microphones 21, 22, 23, 24 and one of loudspeakers 7, 9, 17, 18, 19, 20, the better is the communication may be. However, the possibility of

implementing such an amplification is limited by possible feedback effects caused by sound radiated by a loudspeaker 7, 9, 17, 18, 19, 20, which is received by microphone 21, 22, 23, 24, and is subsequently amplified and radiated by loudspeaker 7, 9, 17, 18, 19, 20.

To reduce such a feedback, in accordance with the example embodiment illustrated in Figure 2, a bandpass filter 32 is arranged between a microphone 30, which may be one of microphones 21, 22, 23, 24, and a loudspeaker 31, which may be one of loudspeakers 7, 9, 17, 18, 19, 20. This filters a signal S generated by microphone 30 and supplies a filtered signal S', which has certain frequency ranges filtered out, for which a decision logic 33 had recognized the danger of feedback. To this end, decision logic 33 determines filter parameters f_c and Q, which are used to adjust bandpass filter 32.

To amplify signal S and/or signal S', amplifiers may be provided. However, the amplifier function may also be provided by the bandpass filter.

Figure 3 illustrates the characteristic curve of a bandpass filter designed as a notch filter, amplification V of the bandpass filter being plotted against frequency f. In this context, f_c indicates the mid-frequency of the bandpass filter and Q its quality. To filter a plurality of frequency ranges, bandpass filter 32 may be arranged as a filter bank, as illustrated in Figure 4. The filter bank may include up to 10 notch filters.

Figure 5 illustrates an exemplary embodiment for a flow diagram implemented in a decision logic 33. In this context, frequency f of signal S is first analyzed in a step 40, and, as illustrated exemplarily in Figure 6, power P of signal S is determined at, e.g., 192, different test frequencies f_n, f_{n+1}, f_{n+2}, f_{n+3}, f_{n+4}, f_{n+5}, f_{n+6}, f_{n+7}, f_{n+8}, which are spaced apart by, e.g., 40 Hz.

It may be provided to average over time the power at test frequencies f_n, f_{n+1}, f_{n+2}, f_{n+3}, f_{n+4}, f_{n+5}, f_{n+6}, f_{n+7}, f_{n+8}, i.e., to develop an average over time, and to test this average value

over time of the power instead of the current power of signal S at test frequencies f_n, f_{n+1}, f_{n+2}, f_{n+3}, f_{n+4}, f_{n+5}, f_{n+6}, f_{n+7}, f_{n+8}. The foregoing may consequently also include the average value of the power developed over a certain time period. Furthermore, power in the present context may include the amplitude or its average value over time. In the present context, further modifications of power, amplitude or their average values over time may also be included, such as normalized values. Thus, for instance, by the power of signal S at a test frequency f_n in the present context, the value of the power of signal S at this test frequency f_n divided by the sum of the power of signal S at all test frequencies f_n, f_{n+1}, f_{n+2}, f_{n+3}, f_{n+4}, f_{n+5}, f_{n+6}, f_{n+7}, f_{n+8} may be understood.

Step 40 is followed by interrogation 41, e.g., whether the danger of feedback exists at a test frequency f_n, f_{n+1}, f_{n+2}, f_{n+3}, f_{n+4}, f_{n+5}, f_{n+6}, f_{n+7}, f_{n+8}. Details pertaining to this query are explained with respect to Figure 7. Provided there is no danger of feedback for any test frequency f_n, f_{n+1}, f_{n+2}, f_{n+3}, f_{n+4}, f_{n+5}, f_{n+6}, f_{n+7}, f_{n+8}, step 40 follows interrogation 41. If, however, the danger of feedback does exist for a test frequency f_n, f_{n+1}, f_{n+2}, f_{n+3}, f_{n+4}, f_{n+5}, f_{n+6}, f_{n+7}, f_{n+8}, then an interrogation 42 follows interrogation 41, e.g., whether signal S generated by microphone 30 has already been reduced, with the aid of the bandpass filter, in the environs of this test frequency.

If signal S generated by microphone 30 has not already been reduced by the bandpass filter, by signal components around the test frequency, then query 42 is followed by an interrogation 43, e.g., whether a bandpass filter is available. If a bandpass filter is available, interrogation 43 is followed by a step 47, in which a bandpass filter is selected and the filter parameters, i.e., the mid-frequency f_c and the quality Q of the bandpass filter, are generated. The mid-frequency f_c is an example of the notch frequency. The notch frequency may be particularly the frequency range about the mid-frequency f_c, which the bandpass filter actually filters out of signal S generated by microphone 30.

Mid-frequency f_c may, for example, be equated to the test frequency, for which feedback has been established. In an example embodiment of the present invention, mid-frequency f_c may also be a test frequency having a correction frequency added to it. This correction frequency is formed, for example, as a function of the power of the signal generated by the microphone at the test frequency at which the power generated by the microphone is a maximum, as well as of the power of the signal generated by the microphone at at least one test frequency next to this test frequency. Thus, the correction frequency may be generated in accordance with:

fkorr = sign*fdist*Pmaxneigh/(Pmax+ Pmaxneigh);

in which:

fkorr represents the correction frequency;

fdist represents the distance between the test frequency at which the power of the signal generated by the microphone is a maximum, and a test frequency having the greatest power which is directly next to the test frequency at which the power of the signal generated by the microphone is a maximum;

Pmax represents the power of the signal generated by the microphone at the test frequency at which the power of the signal generated by the microphone is a maximum;

Pmaxneigh represents the power of the signal generated by the microphone at the test frequency having the greatest power directly next to the test frequency at which the power of the signal generated by the microphone is a maximum; and

sign represents a sign;

the sign being positive when the test frequency, having the greatest power directly next to the test frequency at which the power of the signal generated by the microphone is a maximum, is greater than the test frequency at which the power of the signal generated by the microphone is a maximum, and the sign otherwise being negative.

This is explained in greater detail in the light of the following example:

192 test frequencies f_1, f_2, ... f_{192} are assumed. f_1 is equal to 40 Hz. fdist is 40 Hz for all test frequencies. In

addition, for the powers of the signals generated by the microphone at test frequencies $f1_1$, f_2, ... f_{192}, it is true that:

$P(f_1,\ f_2,\ ....f_{94})=1$
$P(f_{95})=4$
$P(f_{96})=16$
$P(f_{97})=2$
$P(f_{94},\ f_{99},\ ....f_{192})=1$

Then it is true that

fkorr = (-)*40Hz*4/(16+2) = -8Hz

The test frequency at which the power of the signal generated by the microphone is a maximum, is consequently 3840 Hz, and the notch frequency is 3832 Hz.

The correction frequency may also be formed according to:

fkorr = Δf*(Pneighright - Pneighleft)/(Pmax+ |Pneighright- Pneighleft|),

in which:

fkorr represents the correction frequency;

Δf represents the difference between two test frequencies;

Pmax represents the power of the signal generated by the microphone at the test frequency at which the power of the signal generated by the microphone is a maximum;

Pneighright represents the power of the signal generated by the microphone at the test frequency directly above the test frequency at which the power of the signal generated by the microphone is a maximum; and

Pneighleft represents the power of the signal generated by the microphone at the test frequency directly below the test frequency at which the power of the signal generated by the microphone is a maximum.

Based on the above numerical example, it is true in this case that:

fkorr = 40Hz * (2-4)/(16+|4-2|) = -4,44Hz

The test frequency, at which the power of the signal generated by the microphone is a maximum, is consequently 3840 Hz and the notch frequency is 3835.56 Hz.

Quality Q is adjusted to a predefined value of, for example, 1/40 Hz.

If query 43 results in the statement that no bandpass filter is available, query 43 is followed by a step 48, in which the power of signal S is reduced by a reduction factor which may be between 2 dB and 5 dB, e.g., at essentially 3 dB.

If the result of query 42 is that signal S generated by microphone 30 is already being reduced with the aid of the bandpass filter by signal portions around the test frequency, a query 44 follows query 42. Using query 44, the question is whether by a further widening of the frequency range in which the bandpass filter blocks, that is, by a further reduction of its quality Q, a predetermined minimum quality may be undershot.

If by a further widening of the frequency range a predetermined minimum quality may be undershot, query 44 is followed by a step 45, and otherwise by a step 46. In step 45, which corresponds to step 48, the power of signal S is reduced by a reduction factor, which may be between 2 dB and 5 dB, e.g., at essentially 3 dB. In step 46 quality Q is reduced, i.e., the bandpass filter is widened.

After steps 45, 46, 47 and 48 there is a step 49 in which a time between 0.1 s and 3 s is expected.

Figure 7 illustrates an exemplary embodiment for query 41. In this context, first a query 61 is provided as to whether the power of output signal S' of bandpass filter 32 exceeds an output threshold value. If the power of output signal S' of bandpass filter 32 exceeds the output threshold, query 61 is followed by a query 62, as to whether, for example, the ratio PowerRatio3:

> of the power MaxBinPwrPlusNeighbor of signal S generated by microphone 30 is a maximum at the frequency at which the power of the signal generated by the microphone is a maximum, plus the power of

signal S generated by microphone 30 at the test frequency of signal S generated by microphone 30:

which is directly adjacent to the test frequency at which the power of signal S generated by microphone 30 is a maximum; and at which the power is greater than at a test frequency which is also directly adjacent to the test frequency at which the power of signal S generated by microphone 30 is a maximum

to

the average value MeanBinPwrRemainder of the power of signal S generated by microphone 30 of all additional test frequencies of signal S generated by microphone 30

is greater than a feedback-power threshold OutGrdRatioThreshold.

Using query 62, e.g., as provided by this exemplary embodiment, the question is put whether the ratio PowerRatio3:

of the power MaxBinPwrPlusNeighbor of signal S generated by microphone 30 at the frequency at which the power of signal S generated by microphone 30 is a maximum, plus the power of signal S generated by microphone 30 at the test frequency of signal S generated by microphone 30:

which is directly adjacent to the test frequency at which the power of signal S generated by microphone 30 is a maximum; and at which the power is greater than at a test frequency which is also directly adjacent to the test frequency at which the power of signal S generated by microphone 30 is a maximum

to

the average value MeanBinPwrRemainder of the power of signal S generated by microphone 30 of all additional test frequencies of signal S generated by microphone 30

is greater than a feedback-power threshold OutGrdRatioThreshold for longer than a time-ratio-threshold OutBinRatioTimeThreshold. The feedback-power threshold OutGrdRatioThreshold may be between 30 and 40.

It may be provided that query 62 is only answered affirmatively if the global maximum is at a test frequency for longer than a time threshold OutGrdMaxBinTimeThreshold.

To carry out query 62, first of all the local maxima are determined. For this purpose, first of all (for the test frequencies) the first derivative of the power of Signal S with respect to frequency f is determined. From the first derivative of the power of signal S with respect to frequency f a slope signal is subsequently formed, which assumes a first binary value when the first derivative of the power of signal S with respect to the frequency f is greater than or equal to zero, and which assumes a second binary value when the first derivative of the power of signal S with respect to frequency f is less than zero. Subsequently, the first derivative of the slope signal is ascertained. In this context, in an example embodiment of the present invention, the presence of a local maximum of the power of signal S as a function of frequency f is only assumed if the first derivative of the slope signal is less than zero.

Table 1

```
function idx_vec = FinfInfletions(x, flec_thresh)
dtdx = diff(x);
dtdx = dtdx > 0;
dt2dx = diff(dtdx);
idx_vec = find(dt2dx < flec_thresh);
idx_vec = idx_vec + 1;
```

In this context, Table 1 shows an exemplary embodiment of a program written in the language Matlab™, which ascertains

the indices idx_vec of the test frequencies at which there are local maxima according to criteria mentioned above. In this context, x denotes a vector having the powers at the individual test frequencies, and flec_thresh denotes a value between 0 and -1.

The local maximum having the greatest power is regarded as the global maximum.

If query 62 is answered in the affirmative, then query 62 is followed by a query 63, and otherwise by a step 64.

By query 63, the question is put as to whether signal S has a strong harmonic component. For this purpose, in an exemplary embodiment, the question is put whether the ratio:

> of the power of signal S generated by microphone 30 at the test frequency, at which the power of signal S generated by microphone 30 is a maximum

to

> the average value of the power of signal S generated by microphone 30 at all further test frequencies at which the power of signal S generated by microphone 30 has a local maximum

is less than or equal to an additional power threshold RichContentThreshold.

If query 63 reveals that the ratio:

> of the power of signal S generated by microphone 30 at the test frequency, at which the power of signal S generated by microphone 30 is a maximum

to

> the average value of the power of signal S generated by microphone 30 at all further test frequencies at which the power of signal S generated by microphone 30 has a local maximum

is less than or equal to an additional power threshold RichContentThreshold, then query 63 is followed by step 64. Otherwise, feedback is assumed.

In step 64, the sequence is stopped for a predetermined retention time, such as 3 s. After the expiration of the retention time, feedback is negated.

If query 61 yields that the power of output signal S' of bandpass filter 32 does not exceed the output threshold, then query 61 is followed by query 65 which essentially corresponds to query 62. In this context, however, a different feedback power threshold RatioThresholdis used, and not OutGrdRatioThreshold. However, the feedback-power threshold RatioThreshold may also be between 30 and 40.

If query 65 is answered affirmatively, then query 65 is followed by query 66 corresponding to query 63. Otherwise the presence of feedback is negated.

If query 66 reveals that the ratio:

> of the power of signal S generated by microphone 30 at the test frequency, at which the power of signal S generated by microphone 30 is a maximum

to

> the average value of the power of signal S generated by microphone 30 at all further test frequencies at which the power of signal S generated by microphone 30 has a local maximum

is less than or equal to an additional power threshold RichContentThreshold, then the presence of feedback is negated. Otherwise, feedback is assumed.

The feedback detection is not limited to the example embodiment described above. The feedback detection may, for example, be constituted so that only query 65 is provided. The detection of feedback may also be provided so as to replace the example embodiments in accordance with Figure 7 and its binary decision logic by a fuzzy decision logic, e.g., fuzzy logic, or neural networks.

Query 63 as in Figure 7 will be explained below in the light of two signals 80 and 90 illustrated in Figures 8 and 9 in a power-frequency diagram. Power P of signals 80 and 90 is plotted in dB against the index idx_vec of the test frequencies. It is assumed that query 61 yields for both signals 80 and 90 that the power of output signal S' of bandpass filter 32 exceeds the output threshold, and that therefore query 62 follows query 61. It is assumed further

that query 62 receives an affirmative response. The + signs in Figure 8 and Figure 9 denote all test frequencies which have been recognized by the program according to Table 1 as local/global maxima.

In Figure 8, reference numeral 81 indicates the global maximum of signal 80. In Figure 9, reference numeral 91 indicates the global maximum of signal 90. The test frequencies have a separation distance of 40 Hz. The additional power threshold RichContentThreshold amounts to 37.

The ratio:

> of the power of signal 80 at the test frequency at which the power of signal 80 is a maximum

to

> the average value of the power of signal 80 at all further test frequencies at which the power of signal 80 has a local maximum

amounts to approximately 16, and is consequently clearly less than 37. Thus, query 63 would be answered affirmatively, and so the presence of feedback would be negated.

The ratio:

> of the power of signal 90 at the test frequency at which the power of signal 90 is a maximum

to

> the average value of the power of signal 90 at all further test frequencies at which the power of signal 90 has a local maximum

amounts to approximately 73, and is consequently clearly greater than 37. Thus, query 63 would be negated and so the presence of feedback would be assumed.

REFERENCE NUMERAL LIST

1	motor vehicle
2, 3	front seats
4, 5, 6	rear seats
7, 8, 9, 10, 11, 12, 13, 14, 1 5, 16, 17, 18, 19, 20, 31	loudspeakers
21, 22, 23, 24, 30	microphones
32	bandpass filter
33	decision logic
40, 45, 46, 47, 48, 49, 64	steps
41, 42, 43, 44, 61, 62, 63, 65, 66	queries
80, 90	signal
81, 91	global maximum
BinRatioTimeThreshold	time ratio threshold
f	frequency
f_n, f_{n+1}, f_{n+2}, f_{n+3}, f_{n+4}, f_{n+5}, f_{n+6}, f_{n+7}, f_{n+8}, f_1, f_2, f_{44}, f_{88}, f_{94}, f_{95}, f_{97}, f_{98}, f_{122}, f_{192}	frequency points
f_c	mid-frequency
fdist	distance between the test frequency at which the power of the signal generated by the microphone is a maximum, and a test frequency having the greatest power directly next to the test frequency at which the power of the signal generated by the microphone is a maximum
fkorr	correction frequency
MaxBinPwrPlusNeighbor	the power of the signal generated by the microphone at the frequency at which the power of the signal generated by the

	microphone is a maximum, plus the power of the signal generated by the microphone at *the frequency of the signal* generated by the microphone which is directly adjacent to the frequency at which the power of the signal generated by the microphone is a maximum, and at which the power of the signal generated by the microphone is greater than at a frequency which is also directly adjacent to a frequency at which the power of the signal generated by the microphone is a maximum.
MeanBinPwrRemainder	average value of the power of the signal generated by the microphone of all further (tested) frequencies
Q	quality
OutGrdRatioThreshold, RatioThreshold	feedback-power threshold
P	power
Pmax	the power of the signal generated by the microphone at the test frequency at which the power of the signal generated by the microphone is a maximum
Pmaxneigh	the power of the signal generated by the microphone at which the test frequency having the greatest power directly adjacent to the test frequency at which the power of the signal generated by the microphone is a maximum

Pneighleft	the power of the signal generated by the microphone at the test frequency directly below the test frequency at which the power of the signal generated by the microphone is a maximum
Pneighright	the power of the signal generated by the microphone at the test frequency directly above the test frequency at which the power of the signal generated by the microphone is a maximum
PowerRatio3	power ratio
RichContentThreshold	additional power threshold
S	signal
S'	filtered signal
sign	sign
V	amplification
Δf	interval between two test frequencies